**US Army Corps
of Engineers**
Engineer Research and
Development Center

# Assessment of Contaminant Loss and Sizing for Proposed New Bedford Harbor Confined Aquatic Disposal (CAD) Cells

## Lower New Bedford Harbor CAD Cell

Paul R. Schroeder, Carlos E. Ruiz and Thomas J. Fredette

Environmental Laboratory
US Army Engineer Research and Development Center
3909 Halls Ferry Rd
Vicksburg, MS  39180-6199

Prepared for U.S. Environmental Protection Agency, Region 1

# Contents

# Preface

This report describes the sediment characterization, sequential batch leachate testing, modeling and assessment of the lower New Bedford Harbor CAD cell for sizing and contaminant loss. Testing and characterization was conducted on five composite sediment samples collected from New Bedford Harbor DMUs 3 to 37 and 102 to 105. The sediment specimens were sampled and composited by Jacobs Field Services. Each composite was prepared to be representative of a year of dredging. Site water was also collected by Jacobs Field Services at the locations of the two proposed CAD cells. Sediment characterization was performed by GeoTesting Express, Katahdin Analytical Services, and laboratories at the U.S. Army Engineer Research and Development Center (ERDC). GeoTesting Express and ERDC Environmental Laboratory (EL) performed geotechnical analyses. Both Katahdin Analytical Services and laboratories at ERDC EL conducted chemical analysis of the sediment composites and harbor water samples. ERDC EL also conducted Sequential Batch Leaching Testing (SBLT) on the five sediment composites to determine the partitioning characteristics of PCBs and copper in the sediment. The results of the consolidation testing were used to develop void ratio-effective stress relationships and void-ratio permeability relationships for consolidation analysis. The results of the SBLT were used to develop a single set of partitioning coefficients that are representative of all of the composites for PCBs and copper. Consolidation, dredged material placement and contaminant fate and transport modeling for sizing and contaminant loss were performed by ERDC EL. The EPA Remedial Project Manager is Mr. Dave Dickerson of EPA Region 1. The USACE project manager was Mr. Robert Leitch of the New England District.

Drs. Paul Schroeder and Thomas J. Fredette of the Environmental Engineering Branch (EP-E), Environmental Processes and Engineering Division (EPED), EL, and Dr. Carlos Ruiz of the Water Quality and Contaminant Modeling Branch (EP-W), EPED, EL wrote this report.

This study was conducted under the direct supervision of Ms. Deborah R. Felt, Acting Chief of EP-E, and under the general supervision of Dr. Richard E. Price, Chief of EPED, Dr. Beth Fleming, Director of EL, Dr. James R. Houston, Director of ERDC, and Col. Gary E. Johnston, EN, Commander of ERDC.

The authors would like to acknowledge Mr. Michael G. Channell, Mr. Richard Hudson and Ms. Damarys Acevedo for laboratory support.

# Abstract

The US Environmental Protection Agency, Region I (EPA) has proposed using two confined aquatic disposal (CAD) cells as a sediment management alternative for PCB and copper contaminated sediments at the New Bedford Harbor Superfund Site (NBHSS). This report provides EPA with short- and long-term modeling results on estimated contaminant losses and physical sediment behavior during and after filling of the proposed lower New Bedford Harbor CAD cell. This report also provides verification of CAD cell size for containment of the contaminated sediment and capping materials.

The sizing evaluation determined the surficial footprint of the CAD cell required to contain the sediment and capping material considering the side slope requirements, depth to bedrock, the potential for bulking during of dredged material during placement, and the potential spreading of the dredged material from its kinetic energy during its collapse in the CAD cell following placement. The contaminant loss evaluation included both short-term losses (prior to capping) and long-term losses (following capping). Short-term losses include displacement of CAD cell water contaminated by resuspension and stripping of dredged material during placement, consolidation of the dredged material, diffusion from the exposed dredged material, diffusion of contaminants to the upper water column from the contaminated CAD cell water, and mixing of the contaminated CAD cell water with the upper water column by turbulent diffusion and thermally induced overturning. Long-term losses include diffusion and consolidation of the dredged material from the pressure load induced by the thick deposit of dredged material and capping material.

A 650 ft x 650 ft x 47 ft CAD cell is sufficiently large to contain 335,000 cubic yards of sediment and 44,000 cubic yards of capping materials plus the potential bulking during dredging and placement. About 10 ft or 20 to 25% of bulking is expected but this volume of bulking will be recovered with proposed three years of placement operations. An additional 11 ft of consolidation is expected after capping as predicted using the USACE PSDDF model.

Short-term contaminant losses resulting from placement operations are predicted to be about 0.06% of the PCBs and 0.02% of the copper placed in the CAD cell. Resuspension and stripping of dredged material during placement will increase the dissolved contaminant concentrations in the CAD cell water to be approximately equal to the sediment pore water contaminant concentrations. The losses were predicted using the USACE STFATE model to predict sediment resuspension, a partitioning spreadsheet model to compute dissolved contaminant concentrations, and the USACE RECOVERY model to predict losses by diffusion.

Capping with a 3-ft sand layer is sufficient to provide long-term isolation of the contaminants in the dredged sediment from the water column. After capping, the contaminants expelled from the dredged material by consolidation would be contained in the lower foot of the cap as predicted by the USACE CAP model. Without consideration of burial, contaminant breakthrough through the cap at a concentration of 1% of the pore water contaminant concentration will take hundreds to thousands of years as predicted by the USACE RECOVERY model. With burial promoted by

the dredged material settlement, the transport of contaminants through the cap and burial material will take tens of thousands of years.

# 1 — Executive Summary

## Objectives

There are two objectives for this CAD cell modeling study of the proposed lower New Bedford Harbor CAD cell: verification of CAD cell size for containment of the contaminated sediment and capping materials, and quantification of contaminant losses during dredged material placement, from consolidating exposed dredged material prior to capping and after capping, and from long-term diffusion after consolidation becomes insignificant. Containment includes not only capture and storage of the dredged material and capping materials, but also the bulk of the stripped or resuspended materials during placement and the dynamic spreading of the dredged material from the kinetic energy of the discharge during its collapse in the CAD cell. Contaminant losses during placement includes the partitioning of contaminants to the water column from stripped or resuspended dredged material during placement, discharge of pore water from the settled dredged material by consolidation considering the entrainment of water in the dredged material during placement, diffusion of contaminants from the dredged material and through the cap, and the exchange of water in the CAD cell with the overlying water column.

## Testing

Testing and characterization was conducted on five composite samples collected from DMUs 3 to 37 and 102 to 105. The sediment specimens were sampled and composited by Jacobs Field Services. Each composite was prepared to be representative of a year of dredging. Composite 1 was composed of DMUs 3 to 7, and DMUs 102 and 103. Composite 2 was composed of DMUs 8 to 15. Composite 3 was composed of DMUs 16 to 24 and DMUs 104 and 105. Composite 4 was composed of DMUs 25 to 33 and Composite 5 was composed of DMUs 34 to 37. Materials from Composites 1 through 3 are being placed in the upper harbor CAD cell. Materials from Composites 4 and 5 are being placed in the lower harbor CAD cell, along with a portion of Composite 3 materials from the construction of the upper harbor CAD cell located in the area from which Composite 3 was collected. Site water was also collected by Jacobs Field Services at the locations of the two proposed CAD cells.

Sediment characterization was performed by GeoTesting Express, Katahdin Analytical Services, and laboratories at the U.S. Army Engineer Research and Development Center (ERDC). GeoTesting Express performed the following geotechnical analyses: Moisture Content (ASTM D 2216), Specific Gravity (ASTM D 854), Grain Size Analysis with Hydrometer (ASTM D 422), Atterberg Limits (ASTM D 4318), Flexible Wall Permeability (ASTM D 5084), and Incremental Consolidation (ASTM D 2435). ERDC analyzed the composites for moisture content (ASTM D 2216) and organic content (ASTM D 2974). Both Katahdin Analytical Services and laboratories at ERDC conducted chemical analysis of the sediment composites and harbor water samples. ERDC laboratories also conducted Sequential Batch Leaching Testing (SBLT) (ASTM Method D-4793), on the five sediment composites to determine the partitioning

characteristics of PCBs and copper in the sediment. The results of the consolidation testing were used to develop void ratio-effective stress relationships and void-ratio permeability relationships for each of the five composites. The results of the SBLT were used to develop a single set of partitioning coefficients that are representative of all of the composites for PCBs and copper.

# Modeling

## Sizing and Filling

Several modeling tasks were conducted to analyze the CAD filling, sizing and contaminant losses. A cut and fill spreadsheet analysis was perform to determine the size of CAD cell needed to contain the proposed volume of dredged material and to estimate the lift thicknesses of the annual fills for consolidation analysis. A 650' x 650' surface footprint was selected with a side slope of 1V:6H for top 7 ft of depth and 1V:3H for the remaining 47 ft of depth below the existing sediment surface.

## Consolidation

The consolidation of the dredged material was analyzed using the USACE PSDDF model (Primary Consolidation, Secondary Compression and Desiccation of Dredged Fill). The PSDDF model results showed that the CAD cell size was appropriate to contain the proposed volume of dredged material, considering the entrainment of water in the dredged material, the volume of capping material, spreading of dredged material from the placement dynamics, suspended solids retention, and consolidation prior to capping. The consolidation results were analyzed to determine the predicted pore water expulsion rates for contaminant loss predictions both prior to and after capping.

The CAD sizing analysis showed that the center of the lower harbor CAD cell would be filled with 42 ft of dredged material based on its in situ density. Analysis of potential water entrainment in the dredged material during both dredging and placement through the water column yielded an estimate of bulking or entrainment that would result in placement of 52 ft of dredged material and 3 ft of capping material, a total of 55 ft of material in our cell that is 47 ft deep. However, the PSDDF model predicted that in the center section of the CAD cell, 10.3 ft of pore water would be expelled from the placed dredged material prior to capping, primarily from the 10 ft of water that was predicted to be entrained during dredging and placement through the water column (mostly at depth from the first lift placed). Therefore, the depth of fill immediately after capping is 44.7 ft, providing a freeboard of 2.3 ft. After capping, an additional 7.2 ft of pore water is predicted to be expelled in the first 10 years, 9.4 ft of pore water in the first 20 years and 10.9 ft of pore water in the first 40 years. At 40 years, the dredged material is predicted to be 94% consolidated. Based on the PSDDF model results, much of the contaminant losses would be expected to occur during placement and prior to capping.

## Placement

The open water placement of dredged material in the lower harbor CAD cell was modeled using USACE STFATE (Short-Term FATE of dredged material placed in open water) model to predict

the entrainment of water in the deposited dredged material, the mass of dredged material suspended in the water column, the suspended solids concentration in the water column, the settling time, and the vertical and lateral distribution of suspended solids following a barge discharge of dredged material. STFATE model runs were conducted on 500-cubic yard barge discharges at the beginning and of each dredging season to simulate the range of placement impacts for each dredging season and to estimate annual contaminant losses during placement. The STFATE model results show that about 3 to 4% of the fine-grained fraction of the dredged material remains in suspension about 3 to 4 hours after the barge discharge and disperses in the CAD cell water below the loaded draft of the barge, resulting in average TSS concentrations ranging from about 20 mg/L for the first lift to 150 mg/L for the third lift. In a shallow saline environment such as New Bedford Harbor and the CAD cell, the TSS concentration will typically decrease to 50 mg/L within a day and to 10 mg/L within a week.

The discharge plume collapse dynamics were modeled using the USACE SURGE to examine whether the momentum of the discharged material was sufficient to cause the dredged material to run up the side slope and out of the CAD cell. All discharges are assumed to be within the area of the level bottom, a 326-ft square, and no closer to 160 ft from the lip of the CAD cell. The dynamics were examined for all three sediment composites across the range of water depths that would exist during their placement. In all cases the discharged material is not predicted to run up the slope above a depth of about 11 ft below the lip or about 55 ft from the lip. Therefore, the CAD cell is expected to be capable of confining the dredged material during placement.

## Short-Term Partitioning and Contaminant Loss

The contaminants associated with the TSS will partition with the CAD cell water. It is unlikely that the partitioning reaches equilibrium before the particles interact with particles from subsequent discharges, flocculate and settle. The kinetics of PCB desorption in a stagnant water column is sufficiently slow that it may take weeks to reach equilibrium; however, 10 to 20% of the PCBs may desorb in the first day. The partitioning of contaminants to the CAD cell water over the large number of discharges in a dredging season is predicted to be sufficient to achieve a contaminant concentration approximately equal to the pore water concentration of the sediment or dredged material.

The dissolved contaminants and particulate-associated contaminants in the upper portion of the CAD cell will be lost as the CAD cell water is displaced by subsequent barge discharges. The displacement volumes are likely to be about 10 to 20% greater than the volume of sediment being dredged due to entrained water in the mechanical dredge/excavator bucket. This would amount to about 50,000 cubic yards in Year 1, 180,000 cubic yards in Year 2, and 150,000 cubic yards in Year 3. An additional 25,000 cubic yards of CAD cell water will be displaced in Year 3 by cap placement.

Hydrodynamics modeling yielded only low velocities in the water column above the CAD cell, typically less than 0.3 fps. The velocity is sufficiently great to rapidly exchange the water above the CAD cell, typically in one to 3 hours. The velocity is sufficiently low to limit any mixing in the CAD cell water, mostly in the top foot. Therefore, only contaminants in the top foot or two

of the CAD cell are subject to turbulent dispersion and exchange with the water column above the lip of the CAD cell.

The predicted losses of PCBs (Aroclors 1242, 1248 and 1254) during the three years of filling the lower harbor CAD are 310 g in Year 1 (sediment composite 3), 1010 g in Year 2 (sediment composite 4) and 1070 g in Year 3 (sediment composite 5), about 0.035% of the PCBs. The released PCBs are about 81% Aroclor 1242 (about 0.06%), 5% Aroclor 1248 (about 0.009%) and 14% Aroclor 1254 (about 0.018%). About 85% of the released PCBs are predicted to be dissolved. The predicted losses of copper during the three years of filling the lower harbor CAD are 1.9 kg in Year 1 (sediment composite 3), 6.6 kg in Year 2 (sediment composite 4) and 31.4 kg in Year 3 (sediment composite 5), about 0.018% of the copper. About 50% of the released copper is predicted to be dissolved.

Contaminant losses from the CAD cell after placement of the annual lift is driven by diffusion from the CAD cell to the upper exchangeable water column. The annual loss of contaminants by diffusion from the lower water column is limited to about the top 44,000 cubic yards of contaminated CAD cell water after the annual placement operation ceases. The CAD cell is expected to contain about 3.2 kg of PCBs and 15 kg of copper in 348,000 cubic yards of CAD cell water after Year 1, 1.0 kg of PCBs and 6.8 kg of copper in 192,000 cubic yards of CAD cell water after Year 2, and 0.4 kg of PCBs and 6.3 kg of copper in 71,000 cubic yards of CAD cell water after Year 3. Following cap placement, the dissolved contaminants in any remaining CAD cell water will be lost by diffusion.

An additional potential loss of contaminants is the displacement of CAD cell water in the fall or winter by the cold dense water diving into the CAD cell. However, due to the shallow depth of the overlying water column and the mixing that would occur, this mechanism is likely to limit the exchange to no more than 5 feet of water or 71,000 cubic yards in the CAD cell. This would limit the losses to about 20% of the contaminants in the CAD cell water between dredging seasons. Any losses between dredging seasons would be partially offset by decreasing the predicted losses during the next dredging season because the initial contaminant concentration in the CAD cell water at start of the next dredging season would be lower.

The overall potential contaminant losses resulting from placement are 1.3 kg PCBs and 6.5 kg copper from Year 1, 1.5 kg PCBs and 9.7 kg copper from Year 2, and 1.3 kg PCBs and 36 kg copper from Year 3. These losses represent 0.06% of the three PCBs Aroclors (0.1% of Aroclor 1242, 0.02% of Aroclor 1248 and 0.03% of Aroclor 1254), and 0.02% of the copper placed in the CAD cell.

## Long-Term Contaminant Loss from Capped CAD Cell

The contaminant fate and transport from the capped CAD cell were evaluated in two parts. The first part was evaluated during the period of dredged material consolidation using the USACE CAP model, which considers pore water advection induced by consolidation. Ninety percent of the consolidation is completed only after 30 years, but meaningful contaminant transport by pore water expulsion is limited to the first two to four years. The second part was evaluated for the long term, after significant pore water advection ceases. During the long term, contaminant

transport is dominated by diffusion of contaminants from the dredged material and into the cap. Long-term contaminant fate and transport from the capped CAD cell was modeled without considering contaminant degradation or transformation using the USACE RECOVERY model.

The CAP model was run on four separate sections of the CAD cell due to differences in dredged material thickness and predicted settlement. Each section represents about one quarter of the area of the CAD cell. The first section represents the center of the CAD cell and includes the entire section of the cell that has a level bottom. The next three sections are concentric bands around the center covering the sloped area of the CAD cell. Each band has successively thinner dredged material thicknesses and smaller settlements. The CAP model results showed that the contaminants transported from the dredged material by pore water advection and diffusion would be contained in the lower foot of the cap, even in the center section, which had the largest settlement. The contaminant and sediment profiles from the end of the CAP model runs were used as the initial conditions for the long-term modeling using the RECOVERY model.

The RECOVERY model showed that most mobile of the contaminants was PCBs Aroclor 1242, followed by copper and PCBs Aroclors 1248 and 1254. Contaminant breakthrough of Aroclor 1242 and copper through the 3-foot cap is predicted to occur only after hundreds of years of diffusion. Aroclors 1248 and 1254 are predicted to breakthrough the cap only after thousands of years. The model shows that a stable 3-foot cap is highly effective in isolating the contaminated dredged material. Since about 11 ft of settlement is predicted for the center section of the CAD cell, there is a very large potential for up to 11 ft of burial over the life of the CAD cell. If this burial were considered in the long-term fate and transport modeling, the CAD cell would be effective for all contaminants for thousands of year.

## Conclusions

1. A 650-foot square CAD cell excavated 47 ft below the existing sediment surface is sufficient in size to hold the sediments to be placed in the harbor CAD cell and to contain the collapse of the dredged material discharge during placement.

2. About 10 ft of water will be entrained in the dredged material during placement, but all of this water is predicted to be expelled from the consolidating dredged material during the three years of placement.

3. An additional 11 ft of settlement and pore water expulsion is predicted to occur after cap placement.

4. Dredged material resuspension will occur during placement, resulting in TSS concentrations ranging from 20 to 150 mg/L and both dissolved and particulate-associated contaminant release.

5. Dissolved contaminant concentrations in the CAD cell water will become approximately equal to the sediment pore water being placed in the CAD cell.

6. About 2.4 kg of PCBs are predicted to be lost during dredged material placement in the lower harbor CAD cell, 85% of which would be dissolved. About 40 kg of copper are predicted to be

lost during dredged material placement, 50% of which would be dissolved.  These losses represent about 0.035% of the PCBs and 0.018% of the copper being placed.

7.  After capping, the contaminants expelled from the dredged material by consolidation would be contained in the lower foot of the cap.

8.  Without consideration of burial, contaminant breakthrough will take hundreds to thousands of years.  With burial promoted by the dredged material settlement, the transport of contaminants through the cap and burial material will take tens of thousands of years.

9.  A stable 3-ft cap is highly effective in isolating the contaminated dredged material.

10.  Additional losses due to potential diffusion and thermally induced displacement over the winter between dredging seasons could result in about 1.8 kg of PCBs being lost from the CAD cell water, resulting in a total loss of 0.06% from the placement operation.  Similarly, an additional loss of about 13 kg copper could be lost by these mechanisms, resulting in a total placement loss of about 0.024%.

11.  Placement losses between dredging seasons could be controlled by dispersion of powdered activated carbon in the CAD cell.

# 2 – Introduction

## Background

**Report Objectives:** The first objective of this report is to provide the US Environmental Protection Agency, Region I (EPA) with short- and long-term modeling results on estimated contaminant losses and physical sediment behavior during and after filling of two proposed confined aquatic disposal (CAD) cells being considered as a sediment management alternative at the New Bedford Harbor Superfund Site (NBHSS). The second objective is to provide verification of CAD cell size for containment of the contaminated sediment and capping materials.

The quantification of contaminant losses was estimated for dredged material placement, from consolidating exposed dredged material prior to capping, and from long-term diffusion following capping and after consolidation becomes insignificant. Containment includes not only capture and storage of the dredged material and capping materials, but also the bulk of the stripped or resuspended materials during placement and the dynamic spreading of the dredged material from the kinetic energy of the discharge during its collapse in the CAD cell. Contaminant losses during placement includes the partitioning of contaminants to the water column from stripped or resuspended dredged material during placement, discharge of pore water from the settled dredged material by consolidation (considering the entrainment of water in the dredged material during placement), diffusion of contaminants from the dredged material and through the cap, and the exchange of water in the CAD cell with the overlying water column.

**General Setting:** New Bedford Harbor, located in southeastern Massachusetts, is a relatively shallow coastal estuary with depths generally less than 2.5 m (8 ft). It is connected to Buzzards Bay to the south and the main freshwater flow enters in the north from the Achusnet River. A 9 m (30 ft) Federal navigation channel extends from Buzzards Bay into the harbor along with a 7.6 m (25 ft) anchorage and 4.6 m (15 ft) and 3.0 m (10 ft) channels which serve the Town of Fairhaven. The harbor is home to on of the nation's largest commercial fishing fleets.

**Modeling Study Background:** The alternative under consideration includes one CAD cell in the upper harbor (Fig. x.x), and one CAD cell in the lower harbor. The CAD cells being considered would be created by dredging holes into the natural glacial sediments in the bottom of the harbor in order to create storage and isolation for the contaminated sediments. CAD cells are already in use in New Bedford Harbor by the city (reference) and have also been successfully used in New England in Boston, Providence, New London, Hyannis, and Norwalk (Fredette 200x). The footprint of the proposed upper harbor CAD cell has been previously described in Apex (2006) as "Alternative 1" (see Figure 5.2-A, western CAD cell only), and is estimated to contain approximately 420,000 cubic yards (cy) of disposal volume. The exact footprint of the lower harbor CAD cell is yet to be determined, but will be located between the Rt. 6 bridge and

Marsh Island, and will be sized to dispose approximately 300,000 cy of Superfund dredged material and organic silts from excavation of the upper harbor CAD cell.

The material to be placed in the upper harbor CAD cell would be the more highly contaminated Superfund sediments to the north of the CAD cell. The material to be placed in the lower harbor CAD cell would be the less highly contaminated Superfund sediments to the south. Filling of the CAD cells is anticipated to extend over four to five years followed by capping to isolate the contaminants from the environment.

To minimize contaminant loss during filling, the CAD cell alternative proposes to use a perimeter sheet-pile wall around the upper harbor CAD cell, with one or more openings for transit of tugs, barges, and other project vessels. Due to frequent vessel traffic and deeper water depths in the lower harbor, a perimeter silt curtain is proposed for the lower harbor CAD cell instead of a sheet pile perimeter wall.

**Study Approach:**  The study presented here was conducted in two phases.  **Phase 1** involved review of existing reports and databases on site characteristics to assess data sufficiency for modeling the short- and long-term loss of contaminants.  For each of the proposed models the necessary input and boundary conditions were considered in light of the available information. Based on the review, several key data gaps were identified leading to recommendations for specific field and laboratory work.  In order to fill the data gaps identified in Phase 1, a field sampling and laboratory analysis plan was developed.  Field sampling involved collection of both sediment cores and site water and occurred in xx 2009.  Laboratory analysis proceeded in the following weeks.  **Phase 2** involved modeling short- and long-term losses using the existing and/or newly collected data.  These models are briefly described here and greater detail is provided in later sections of this report.  Model descriptions for STFATE, PSDDF, and RECOVERY/CAP are based on Schroeder et al. (2004).

**STFATE.**  The short-term fate of dredged material model (STFATE) mathematically models the physical processes determining the short-term fate of dredged material disposed at open-water sites within the first few hours after disposal.

Major Capabilities:
        ● Estimates receiving water concentrations of suspended solids, dredged material liquid and suspended phases, and dissolved contaminants as a function of time and location.
        ● Estimates the percentage of suspended solids deposited on the bottom as a function of time and location and the thickness of deposition.

**Hydrodynamic Model – need more better description similar to other models**

**SURGE. – need similar text**

**PSDDF.**  The consolidation, compression, and desiccation of dredged fill model (PSDDF) provides a mathematical model to estimate the storage volume occupied by a layer or layers of dredged material in a confined disposal facility (CDF) or for underwater placement as a function of time.

Major Capabilities:

● Determines the final or ultimate thickness and elevation of multiple lifts of dredged material placed at given time intervals.

● Determines the time rate of settlement for multiple lifts and therefore the surface elevation of the dredged material fill as a function of time.

● Determines the water content, void ratio, total and effective stress, and pore pressure for multiple lifts as a function of time.

**RECOVERY/CAP.** The contaminant release from bottom sediments model (RECOVERY/CAP) is a screening-level model to assess the long-term impact of contaminated bottom sediments on surface waters. The model couples contaminant interaction between the water column and the bottom sediment, as well as between the contaminated and clean bottom sediments. Processes incorporated in the model are sorption, decay, volatilization, burial, resuspension, settling, bioturbation, and pore-water diffusion.

Major Capabilities:

● Allows for a rapid analysis of recovery scenarios for contaminated sediments and cap evaluations.

● Simulates behavior of organics in a real system with a limited amount of data.

● Predicts desorption of contaminants from sediments.

**Phase 1**

The NBHSS project sediment database and technical reports on New Bedford Harbor sediment characteristics, water quality, sub-surface geology, and ground water flow were reviewed to assess the existing information to determine whether any additional data needed to be collected for the planned modeling activities. These sources provided considerable information that could be directly used as part of the modeling efforts (see Phase 1 report, Appendix x). Data types that were determined to be sufficient included foundation properties, sediment copper and PCB concentrations, sediment grain size, water content, specific gravity, and Atterberg limits. Data on sediment pore water contaminant concentration and partitioning to the water column during dredging and disposal were less well understood and were therefore identified as important data gaps.

The specific recommendations identified in the Phase 1 report (Appendix x) were as follows:

**Annual Dredging Sediment Composites:** Seven[1] sediment composites, five in the Upper Harbor and two in the Lower Harbor, should be collected, representing the average of the sediment DMUs to be dredged in each of the years. Care should be taken to collect sufficient samples from each DMU to form each composite so that each composite is representative of the average PCB, Cu, TOC and DOC concentrations, as well as the average water content, silt and clay content, and oil and grease content of the sediment being dredged each year.

---

[1] Subsequent to this early assumption of seven composites an analysis of annual dredging volumes and their estimated contaminant concentrations resulted in a decision to reduce the total number of anticipated sediment composites to five; three for the upper harbor and two for the lower harbor. This is discussed in the next section.

**Sediment Analysis Needs for Each Composite:**
Bulk sediment concentration of Total PCBs (based on 18 PCB congeners as performed for baseline monitoring), Aroclor 1242, Aroclor 1254, Cu, AVS, Oil and Grease, TPHs, and TOC

Pore water total and dissolved concentrations of Total PCBs (based on 18 PCB congeners), Aroclor 1242, Aroclor 1254, Cu, AVS, and Organic Carbon. Also, Salinity, TDS, and TSS

Geotechnical properties including water content, specific gravity, organic content, Atterberg limits, and grain size distribution

**Site Water Samples:** Site water should be collected from the proposed CAD sites for analysis and use for testing.

**Site Water Analysis Needs:**
Site water total and dissolved concentrations of Total PCBs (based on 18 PCB congeners), Aroclor 1242, Aroclor 1254, Cu, AVS, Oil and Grease, TPHs, and Organic Carbon. Also, Salinity, TDS, and TSS

**Testing Needs:**
**Standard Elutriate Tests** should be run on each of the seven sediment composites using the appropriate proposed CAD site water to predict short-term losses during disposal. The test should analyzed for elutriate total and dissolved concentrations of Total PCBs (based on 18 PCB congeners), Aroclor 1242, Aroclor 1254, Cu, AVS, Oil and Grease, TPHs, Organic Carbon and also TSS.

**Sequential Batch Leaching Tests** for partitioning characteristics should be run on each of the seven sediment composites to determine partitioning characteristics for PCBs (total based on 18 PCB congeners, Aroclor 1242, and Aroclor 1254) and Cu. Four cycles should be used for PCBs and seven cycles should be used for Cu. The test should analyzed for leachate total and dissolved concentrations of Total PCBs based on 18 PCB congeners, Aroclor 1242, Aroclor 1254, Cu, AVS, Oil and Grease, TPHs, Organic Carbon and also TSS.

**Standard Oedometer Consolidation (ASTM D2435) and Permeability Tests** should be run on each of the seven sediment composites to determine consolidation properties for consolidation of the dredged material in the CAD sites and for seepage of pore water from the CAD sites.

As a result of the review and the anticipated dredging schedule which would place individual, annual layers in the cells it was determined that data to characterize each lift in more detail would provide greater confidence in the modeling results. This resulted in a plan to collect both sediment and water chemistry data from samples composited to represent each of the proposed annual dredging cycles. The reasoning for collecting sediment chemistry data for these samples, even though sediment chemistry was determined to be adequate during the data gap review, was that understanding the relationship between observed pore water chemistry and chemical partitioning behavior relative to the original sediment matrix was critical.

**Field Sampling Plan**

**Pre-plan Dredging Scenario Analysis.**  As the project proceeded from Phase 1 to the Field Sampling Plan, the team discussed the possibility that dredging would be done over a five year schedule instead of a seven year schedule.  The discussion further identified concerns that if modeling were based on a five-year assumption, but the actual schedule turned out to be seven years, that the modeling may not be representative, particularly if the inner harbor segments under the seven-year scenario exhibited much higher contaminant concentrations than they would under the five-year scenario.

In order to assess this possibility, and prior to preparation of the field sampling plan, an analysis of dredging volumes and predicted composite sediment concentrations was conducted to estimate the range of average concentrations among the composites.  This analysis used the estimated total dredging volumes (including over-dredge allowance) calculated for each dredging management unit (DMU) and reported in Foster Wheeler (xxxx), Table 1 and sediment chemistry data from the NBHSS project database.

The first step involved discussion with the NBHSS RPM to determine which DMUs were being considered for placement in the CAD cells.  This discussion confirmed that sediments from MU1-24 along with MF-102-104 would be isolated in the Upper Harbor CAD cell and that MU25-37 would be directed to the Lower Harbor CAD cell.  Thus, all DMUs in the Foster Wheeler table except for the four labeled VU were further considered.

The next step involved adjusting volumes in Table 1 to reflect the dredging progress since the original calculations were made.  Several DMUs were assumed to be completely dredged (MU-1, MU-2, MU-4, MU-11), based on a 2004-2007 dredging footprint overlay (Fig. x.x - Jacobs Fig. 1.1).  Dredging conducted in FY08 had removed portions of MU-10 and MU-11 and FY09 dredging was expected to remove various amounts of MU-19-24.  Based on this information, an estimate of the area remaining to be dredged for these eleven DMUs was used to adjust the original volumes (Table x.).

The next step involved geographic grouping of the DMUs into the seven- and five-year scenarios.  In the first scenario, the upper harbor would be dredged over five years with a lift of sediment placed into the upper harbor CAD each year and the lower harbor would be dredged over two years with the sediment lifts placed in the lower harbor CAD cell.  The second scenario would involve accelerating the upper harbor dredging over a three-year timeframe while the lower harbor remained on the same two- year schedule.  DMUs were then grouped based upon volume and geographic proximity to distribute the estimated volumes as evenly among the events/years as possible (Table x.).  For the purpose of this analysis, dredging DMUs were assigned to one year or another with no splitting, although it should be recognized that actual operations may involve partial dredging of DMUs to achieve balanced volumes.

Once the DMUs had been grouped, estimated average values for total PCB (tPCB), Cu, TOC, and percent silt/clay were calculated for each DMU grouping.  In order to evaluate any differences between the two dredging scenarios and also to assess the impact that higher

concentrations might have on assumptions for subsequent modeling, two different estimates were created for the upper harbor lift scenarios. One a simple average of the individual DMU concentrations and the second a weighted average based on DMU volume.[2]

Data for the DMUs were extracted from the NBHSS project database for tPCBs, copper, total organic carbon (TOC), and grain size. Data were filtered to eliminate records with tPCB concentration values below 10 mg/kg, as these were unlikely to be dredged based on the project clean-up goals. Data were also filtered to eliminate those samples that were collected in portions of the DMUs following dredging, as these would likely not represent sediments to be dredged in the future. The number of data points for tPCB ranged from 4 to 204 per DMU (Table x). Copper (0-7), silt/clay (0-7), and TOC (0-7) had far fewer data points per DMU. Means and standard deviations were calculated for each DMU on tPCBs, Cu, percent silt/clay, and TOC. The PCB mean plus two standard deviation data showed extreme heterogeneity in the upper harbor (Fig. x). Overall the data showed a downward trend from the upper to lower harbor. The extreme heterogeneity observed was a result DMUs which had one to five samples that were considerably higher than the remainder of the data for those DMUs. For example, DMU-102 had one sample at 46,000 mg/kg out of the 59 data records while the next highest reported value was 4,800 mg/kg. DMU-3 had five values of 26,000, 12,000, 12,000, 8,800, 7,300 mg/kg out of the 62 data records with all of the other 57 data points below 4,000 mg/kg.

## PCB by DMU



---
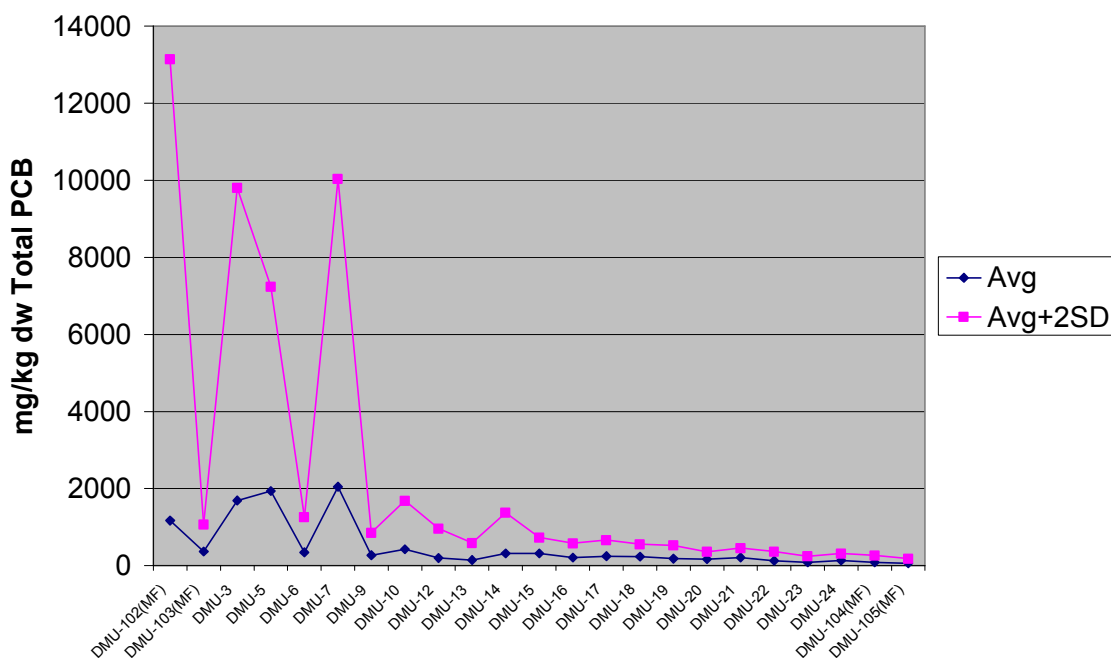
[2] The calculation of the DMU group means from individual DMU means can produce a somewhat imprecise estimate of the true mean of the data, but was done for expediency and was considered acceptable for the planning level effort. Subsequent analysis of the DMU group means based on the individual data points across all DMUs in the group showed generally similar results to the "mean of means" analysis and is discussed later.

The mean tPCB, Cu, TOC, and percent silt/clay data from each DMU were used to estimate the mean concentration of the five and seven lift scenarios. The average tPCB, Cu, TOC, and percent silt/clay for the two scenarios did not result in any grouping exhibiting markedly higher contaminant concentrations. Both the five and seven lift scenarios calculated that the average tPCB concentration in the first lift would be between 1000 and 1500 mg/kg with later lifts reflecting the down harbor gradient.

As mentioned earlier, the primary calculations involved a "mean of means" approach, but this was later followed up by averaging all data across each DMU grouping in order to make sure that undue bias had not occurred in the initial analysis. Results of these calculations showed slight differences from the previous calculations, but from a modeling perspective they were not considered to be of consequence. Had there been differences of an order of magnitude or more, then additional analyses might have been warranted.

As a consequence of these analyses, it was decided by the team to proceed with collection of sediment composites representing the five lift scenario as the modeling based on this scenario should be representative of the reasonably foreseeable range of dredging scenarios. The five groups of DMUs were then used as the basis for the Field Sampling Plan (Figures x-x).

**Sediment and Water Sampling**

Sample collection was under the direction of the New England District and performed under contract by Jacobs Engineering. The contractor was required to prepare addendums to existing project work plans, including the Field Sampling Plan (FSP), Quality Assurance Project Plan (QAPP), and Site Specific Safety and Health Plan (SSHP) associated with the field sampling and data collection (Jacobs 2009 – FSP addendum).

Sediment collection involved taking cores from 10 locations in each of five identified groups of dredging management units (DMU) to create five composite samples for analytical testing. Each composite sample was created by taking cores from 10 locations to estimated dredging depth. A volume weighted, stratified random selection process was used to select core locations within each group of DMUs. A total of 50 cores were collected as part of this effort. Sediment from each of the 10 locations/group were homogenized to create a single composite/group.

The process used for core location selection was described in the FSP as follows:

"Locating cores within DMUs was performed with the aid of GIS. For a DMU with one or more cores assigned, the average Z* sediment thickness was calculated for that DMU, GIS was then used to identify Z blocks containing an average Z* thickness (+/- 0.5 feet). Of the Z blocks containing an average Z* thickness (+/- 0.5 feet) GIS was used to randomly select one Z Block and place the first core in that block. For DMUs with multiple cores the second core was randomly placed in a Z block identified as containing greater than average Z* sediment thickness. For a DMU with more than two cores, the third core was randomly assigned using GIS to a Z block containing less than the average Z* thickness of sediment. Several cores were manually shifted to avoid known obstructions such as power cables.

Areas assumed to be dredged through 2009 were not considered for sediment core locations.  In areas without Z* data, cores were placed randomly within DMUs using GIS.  The number of cores placed in DMUs without Z* data was determined on a volume weighted basis similar to the DMUs with Z* data."

Sufficient sediment was taken in order to provide the necessary volume for the tests specified below and to provide five liters of sediment/composite (total of 25 liters) to ERDC for sequential batch leaching testing to be conducted in Vicksburg, MS.   The samples were shipped within seven days of collection or within two days of compositing, as identified in the QAPP/FSP.

The contractor also collected water from the locations of the two proposed CAD cells in NBH.  Samples were collected from the mid-water depth for background water quality.  Additionally, the contractor collected 50 liters of water from these locations for delivery to ERDC.  This consisted of 30 liters from the upper CAD cell location and 20 liters from the vicinity of the lower harbor CAD cell location.  This water was preserved and shipped by the contractor to ERDC as specified in the FSP.

The five composites were analyzed for bulk sediment concentration of Total PCBs (based on 18 PCB congeners as performed for baseline monitoring), Aroclor 1242, Aroclor 1254, Cu, Acid Volatile Solids (AVS), Oil and Grease, Total Petroleum Hydrocarbons (TPHs), and Total Organic Carbon (TOC).  Analytical methods were consistent with the project methods used in recent, past sample efforts (QAPP/FSP).

Pore water samples were extracted from a portion of the composite and analyzed for total and dissolved concentrations of Total PCBs (based on 18 PCB congeners), Aroclor 1242, Aroclor 1254, Cu, AVS, and Organic Carbon.  Pore water samples were collected using a refrigerated centrifuge and filtration method (Mudroch & Azcue 1995) or other approved method as proposed in the QAPP.  The total concentrations were analyzed following sample centrifugation and the dissolved concentrations were analyzed following filtration.  Samples were also analyzed for salinity, TDS, and TSS.  Water samples from the two proposed CAD cell locations were also analyzed for the same suite as the pore water samples.

Standard Elutriate Tests were also run on each of the five sediment composites using the appropriate proposed CAD site water to predict short-term losses during disposal.  The tests were analyzed for elutriate total and dissolved concentrations of Total PCBs (based on 18 PCB congeners), Aroclor 1242, Aroclor 1254, Cu, AVS, Oil and Grease, TPHs, Organic Carbon and also TSS.  Analytical methods were consistent with EPA/USACE (1998 – see Section 10) or with the project methods used in recent, past sample efforts (QAPP/FSP).

Each of the five composites were analyzed for geotechnical properties including water content, specific gravity, Atterberg limits, and grain size distribution.  Analytical methods were consistent with the project methods used in recent, past sample efforts (QAPP/FSP).  Standard oedometer consolidation (ASTM D2435) and permeability tests were performed on each of the five sediment composites to determine consolidation properties for the dredged material in the CAD sites and for seepage of pore water from the CAD sites.

Field sampling plan – overall approach, DMU grouping, compositing, volumes, etc. - TF
Field sampling – confirmation of planned approach or deviations - TF

References

Fredette, T. J. (2006).  Why confined aquatic disposal cells often make sense.  Integrated Environ. Assess. Man. 2(1): 1-4.

Schroeder, P. R., Palermo, M. R., Myers, T. E., and Lloyd, C. M. (2004). "The automated dredging and disposal alternatives modeling system (ADDAMS)," *Environmental Effects of Dredging Technical Notes Collection* (ERDC/TN EEDP-06-12), U.S. Army Engineer Research and Development Center, Vicksburg, MS. *http://www.wes.army.mil/el/dots/eedptn.html*

DRAFT

DRAFT

Outline - New Bedford Harbor CAD Cell Evaluation Report

TOC
List of Figs
List of Tables

Executive Summary

Introduction

       Purpose of Report
       New Bedford Harbor Background
              General setting
              CAD cell loci and initial assumptions (5 dredging seasons)
       General study approach
               additional data collection
              laboratory tests
              modeling

Data Sources, Collection and Analysis
       Existing data
       Field sampling plan – overall approach, DMU grouping, compositing, volumes, etc.
       Field sampling – confirmation of planned approach or deviations
       Laboratory tests
               Geotechnical Characterization
                     Methods (physical tests - (water contents, specific gravities, grain size distribution, Atterberg limits, consolidation characteristics from standard oedometer test consisting of void ratio-effective stress relationships for range of dredged materials and void ratio-permeability relationships for range of dredged materials)
                     Results
                     Analysis for consolidation properties
               Chemical Characterization
                     Methods (chemical tests - (bulk sediment chemistry, water chemistry, standard elutriate testing, pore water chemistry,SBLT)
                     Results
                     Analysis for partitioning characteristics

Modeling
       Modeling assumptions for CAD cells, foundation materials, hydrodynamics, etc.
       Sizing Analysis
               Cut and Fill Calculations
               Description of PSDDF
               Description of Model Runs
               Results
       Placement Analysis
               Description of STFATE
               Description of Model Runs
               Results
               Description of Surge
               Description of Model Runs
               Results
       Contaminant Loss Analysis
               Placement Losses
                     Resuspension and Partitroning Analysis
                     Water column exchange modeling
                     Displacement Losses

Diffusion Losses
Thermal Overturn
Post-Capping Short-term Losses
Description of CAP
Description of Model Runs
Results
Post-Capping Long-term Losses
Description of RECOVERY
Description of Model Runs
Results

Discussion
Sediment & water data results relative to historic data
Interpretation of modeling results (relative losses)
Model results confidence/uncertainty
Overall assessment

Conclusions and Recommendations
Conclusions
Final design needs/considerations
Remaining data gaps?

Appendices (both printed and CD)